Issues of Tacit Knowledge, within 3D printing for artists Designers and Makers

Stephen Hoskins; University of the West of England; Bristol, Avon. UK

Abstract

The creative industries are directly interfacing with 3D printing technology and how it is changing the practices of many artists and designers across the globe. However for the creative community it is not possible to take on a new manufacturing technology without an inherent understanding of materials. All too often with the adoption of new technology, in whatever discipline, one can instantly tell a work that has been dictated and created by the simple constraints of a new process. It will not possess any of the inherent material or aesthetic qualities that are obvious in a piece that is made so skillfully that it transcends the process. Therefore the adoption of 3D printing technology is not simply a matter of detailing scientific or engineering advances to a new process. A selection of case studies of leading designer makers who demonstrate both skill and technical expertise will be presented to reveal the spread and problems of the technology over a number of diverse disciplines.

Introduction

Now that 3D printing or additive manufacture, has gained a more universal acceptance, we now need to consider the processes from a user perspective rather than from an engineering or science perspective, which was essential to create the machine. Here I will try and demonstrate why a different perspective may be advantageous and I will use a creative approach to illustrate this alternative view. In order to 3D print a successful artwork currently requires a high degree of skill, but the problem at the moment is the material properties deny the craft skill. The process not only has a physical disconnect between the maker and the object, but also has the added disadvantage that this physical disconnect is mediated yet further through the digitisation process. Set against this is the necessity for a tacit understanding of materials, which can only be gained by the hands-on acquisition of knowledge through practice, which is essential to the creation of any good quality artefact to which we might ascribe a high degree of skill. Whether it is a 14th Century tin glazed Majolica bowl from Deruta in Italy or a table from the contemporary furniture maker Fred Baier

However the fundamental dichotomy is the reconciliation of learned tacit knowledge of materials, essential in the creation of a quality artefact, in any manufacturing process (whether analogue or digital). Set against a 3D Printing process that removes and automates the essential co-ordination of hand and eye. In addition the 3D Printing process involves laying down a material in a new way that bears little relation to the processes that have in the past been used to create an artefact in a familiar manner. At this point I may be opening myself up for criticism for holding what in some circles may be seen as an old fashioned view, in that I firmly believe in a visual aesthetic and the need to learn craft skills in order to create art of value that combines both an appreciation of form and content. I am also in the same camp as Richard Sennett in his treatise 'The Craftsman', in that I believe these skills have to be learnt by familiar understanding and repetition of practice.

'All craftsmanship is founded on skill developed to a high degree. By one commonly used measure, about ten thousand hours of experience are required to produce a master carpenter or musician. Various studies show that as skill progresses, it becomes more problem attuned, like the lab technician worrying about procedure, whereas people with primitive levels of skill struggle more exclusively on getting things to work.'1 Sennett

So how do I believe that the creative community will deal with this problem and adopt these new technologies? I may need to qualify here what I mean by adoption: I do not believe that the early adoption of a process is representative of a new field. Early adopters tend to create artefacts that, at best look as though they are using a very specific technology that is instantly recognisable as that specific technology in itself and not a means of communicating an idea through an appropriate tool. We are at the cusp of this stage of 3D Printing creatively. The most innovative work comes when the technology becomes more commonplace and then the images, objects or artefacts created using the technology simply as a means to an end and not as a means to represent the process or technology.

I can best describe the rise of this technology in the same vein as the introduction of mechanisation into the crafts during the Victorian Era. This is perhaps best illustrated by George Sturt, in his famous text 'The Wheelwrights Shop' 2 documenting the period between 1884 and 1891, when farm carts were still wholly made by hand, just before the general acceptance of machinery into the trade. Sturt comprehensively makes the argument for an understanding of materials in order to make the best quality of artefact. His employees had a complete and tacit knowledge of all of the elements that went into the growing, harvesting and seasoning of the locally sourced timber they used. However we are now in a different world where the knowledge required of a skilled craftsperson is very different and will similarly have to change in the future.

Sturt describes the transition of his family business to mechanisation:

'But eventually - probably in 1889 - I set up machinery: a gas engine, with saws, lathe, drill and grindstone. And this device, if it saved the situation, was (as was long afterwards plain) the beginning of the end of the old style of business, though it did just bridge over the transition to the motor-trade of the present time.'

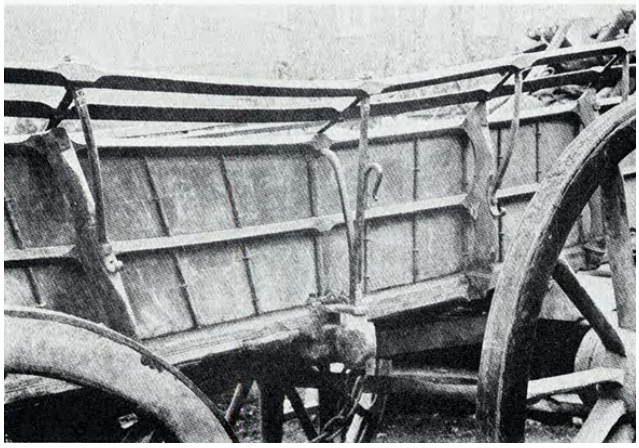

Figure 1 *Handmade cart from the workshop of George Sturt*

What is interesting here is that all of the machinery Sturt describes is still a complete part of the modern craftsperson's toolkit. In fact many craft woodworkers making furniture today - in addition to being completely au fait with powered hand and machine tools, would also possess a CNC router- as well as a hand chisel. The crux of this argument is simply that - the adoption of new technology requires a new set of skills, without throwing out the skill and material knowledge inherent in all of the previous technologies. It crucially requires an understanding that these technologies are no more or no less than a new set of tools, which require time to become familiar with. What they should not do is dictate the practice. All too often with the adoption of new technology, in whatever discipline, one can instantly tell a work that has been dictated and created by the simple constraints of a process - It will possess none of the inherent material or aesthetic qualities which are obvious in a piece made so skillfully that it transcends the process. One instantly looks at the content whilst fundamentally understanding the level of skill required to create the piece, but not having to question its integrity or imperfections. For example, if one compares the classic Arne Jacobson bent plywood butterfly chair which demonstrates all of the inherent material qualities and the low cost IKEA Vilmar chair which is built to solely to match a specific price point.

I will illustrate my argument in more depth using 3 examples of talented creative practitioners who approach 3D Printing Technology in very different ways, drawn from interviews undertaken for my recent book on 3D printing for artists[3]

Case Studies

Jonathan Keep

Jonathan Keep is a well respected, UK ceramic artist. His practice includes sculptural works, some functional thrown ware as well as 3D printing. In relation to 3D printing Jonathan's view is: 'As far as I am concerned 3D is just another tool that enables your work with clay, sometimes I am throwing forms and cutting them up, other times I'm using coil building, other times I'm using 3D printing.'

He first started 3D printing in 2011 after seeing the work of the Belgian Design Company Unfold Labs, who added a pressure driven syringe to a Bits from Bytes RapMan printer in order to print clay. Jonathan was inspired to purchase a Bits from Bytes RapMan self build machine of his own. He then made the same modifications with a converted print head to take a pressurised syringe, which is used to extrude ceramic slip casting clay through a nozzle.

Figure 2 *Icebergs, 3D printed extruded porcelain pots by Jonathan Keep*

It may be helpful to provide a little technical clarification. The Axon software slices the 3D model and generates a series of linear tool paths, which are sent to the 3D printer to control the movement of the print head. Jonathan configures the software so that it only builds the external surfaces. The infill information the software generates is excluded from the build. This means the object will be built with a wall thickness that is determined by the width of the syringe nozzle he is printing with and cannot be varied. This is different to the normal process for a 3D printer, which is to create a virtual solid object in 3D software, with the option of a specified wall thickness. The code is written using 'Processing' - an open source programming language based on JavaScript. 3D files are captured or exported from these sketches and cleaned up in the open source 3D software 'Blender'[4] In the Blender program Jonathan may adapt and recreate the initial mesh quite considerably. The 3D file is then further processed through the printer software, (Bits from Bytes, BfB Axon) to produce 'g code, developed for CNC milling that is read by the Bits from Bytes 3D printer. Axon is a user-friendly version of Skienforge, the standard freeware software for low cost 3D printers.

Currently around a third of Jonathan's work involves 3D printing, mainly for the more sculptural pieces, but he still uses throwing for making his range of domestic ware. Jonathan explained that he uses 3D printing as a way to realise forms that have been computer generated:

'The patterns and systems that go into making natural forms can be explored in computer code, and it is to realise this code as physical objects that I am using 3D printing. This is just not possible with traditional processes. However the printing technique I use is very close to the technique of traditional coil build pottery – it could almost be seen as mechanical coiling process. What printing offers is a new way of working that includes the computer as a tool that for me becomes much more integral to the way of creating forms.'

'The way of working is often more important to me and less so the qualities. Because I am interested in the mechanics of form, computer coding can start to give you an insight into that. I have taught myself basic Java coding so the actual forms aren't like the usual ones you would get in Rhino, but I am using code libraries for a cylinder (for example) then I can start distorting that cylinder through random mathematics etc. So I then get a mesh that I can capture on computer, then output to a printer and create a physical form, and there is no other way I could do that (by hand) or to do it another way would be pointless'. This belies the notions of material qualities usually so important to a craftsperson.

Figure 3 *Random Growth 3D printed extruded ceramics by Jonathan Keep*

Jonathan states that the physically printed ceramic forms are solely created with 3D printing but thereafter, traditional technologies are used to fire and glaze the objects. However during the build process he intervenes either with his hands - to keep a section supported whilst printing - or with a hairdryer, to quickly dry a section so that it will not collapse during the build process. In essence Jonathan has a very interactive build process, synonymous with being a hands on traditional thrower 'I don't go beyond 45 degrees but even then it bulges and I'm in there with a hairdryer drying it as quickly as I can, but I've given up – bowls just don't work'.

Jonathan's uses a syringe that deposits approximately 1mm of clay width in the horizontal axis, with 2 mm in the vertical axis and runs the syringe at a pressure of 3 bar. This means that Jonathan has to clean up the print as it finishes because you cannot just turn off the pressure. At the CFPR we print clay with a much finer auger system (a type of screw thread between the syringe and the deposition head) to create a more even flow and combat some of the start and stop problems. However Jonathan's has an interesting view on these issues:

'My attitude to the barriers of 3D printing is very pragmatic - I don't see them as barriers. I work within the limitations of what I've got. People are saying to me – aren't there other ways you can feed in clay to extend your syringes? and so forth (to make a bigger pot) what I do is I cut up the mesh in Blender and will do 2 or 3 prints to get more scale, then assemble them and because they fit perfectly you just put them with the other half. I'm more concerned with the process than trying to reengineer the machine every time. Its what you do with it that's the most important aspect, so once I saw the Bits from Bytes Rapman had a syringe on it I though that's the one for me.' Jonathan can build 2 halves of an object, and using slip, stick them together as greenware, quite easily, using a traditional craft practice. I would argue this is a really interesting solution using tacit knowledge of materials to solve a problem, by making the most of the inherent properties of clay. He elaborates on his process:

'printing is a very small part – a bit like throwing – of the process. To get to the finished article there are all sorts of other traditional ceramic processes that take place first. You know the glazing and the firing etc.' This is particularly true of ceramics and perhaps less so with some of the other processes and disciplines, but it is clear that all of the craftspeople I talked to have some form of intervention in the process of making. These aspects of Jonathans practice seem to be at odds with his comments regarding progress on material qualities.

Marianne Forrest

Figure 4 *Paelolith unique watch by Marianne Forrest, laser sintered titanium*

Marianne Forrest makes timepieces that range from the tiniest of wristwatches to huge architectural installations for urban spaces. Marianne calls herself a maker or 'designer maker' 'I try to re-define the traditional watch and the way it is worn by expanding its potential for hanging and draping on different parts of the body and clothing'. Her introduction to 3D printing technologies began around 2007, when direct metal laser sintering became available and Marianne started learning Rhino. She had played with the technology earlier, but clearly states there was no incentive until suitable materials were accessible. She learnt the technology by actually making a piece of work and working through the tutorials. When asked what proportion of her work was now made with 3D printing, Marianne makes a number of 3D printed items but has only made a few different designs. For example she can get 70 watch cases for her miniature watch 'sho' in one build. In terms of the qualities that 3D print has to offer Marianne is very clear,

when describing her most complicated work to date, the unique watch 'Paelolith', she explained the complexities of the build process:

'Paleolith was actually built in six parts then Welded together. Because it's a very different process, (to making a piece by hand) especially with the support structure and the cleaning up required - this single piece took me six months to clean up! However one of the interesting things about it is I couldn't have physically made it like this by hand. Each one is made using a comb that I had stacked together and then cut, there is no way I would ever have made that by hand, it would have taken me a couple of years. So six months is really quite quick!'

It is possible to see from the comb structure that it would have been impossible to get tools into the tight spaces in order to cut them, similarly casting would not have worked as the moulds would have been far too complicated. As a counterpoint to the length of time and work required by Paleolith, Marianne created a series 'Sho', in which designed the objects parameters so it would require no cleaning up. She made sure that she specified the angles avoiding overhanging features of greater than 30 degrees, thus creating a deliberately self supporting work which only had a tiny little spigot in the middle to connect it to the base of the build structure in the bed: 'when I got it back from printing I actually didn't do any cleaning up - just gave it a quick polish and there you go.'

Figure 5 *Sho by Marianne Forrest, laser sintered titanium*

'When it comes to the watch cases, with the absolute smallest one, I had to make it in Rhino software because you can't physically make it that small, which was interesting and a really good use of Rhino, as it was absolutely pared down – they also sell like hotcakes! Marianne offered further details that explain how 3D Printing is crucial to the whole process of getting the movements to fit: 'I took each wall thickness right down to the last possible parameter – you can only do that in 3D Prototyping you just can't cast it, it will shrink or move or lose something and then the movement doesn't fit; Very logical. So I like the intensity of that tinyness - but I also like the wear-ability'.

Of the process of drawing she says 'I try to cut things like I would at the bench, I'm struggling with it at the moment, having doing the earlier pieces I'm back to the cutting and filing inside the computer, So I started with a box and almost everything was Boolean difference, but I'm trying to make it all subtractive manufacture. That paradox is quite interesting to me and the paradox between the hand and the screen, as most people don't think of it that way (i.e. as an approach to the technology)'

Figure 6 *Tiny Titanium drop by Marianne Forrest*

This seems to me a very interesting way of working, where 3D printing is in itself an additive process and the software therefore allows you to build the object in a similar additive manner. It then seems unusual to deliberately work subtractively. I wonder if this is something that is only inherent to a person with many years of hand crafted practice who has then learnt digital technologies as opposed to a person who has grown up with both.

She also comments: 'Rather than trying to stretch the technology, I'm just trying to make things in different ways. What interests me is the way you use your hands and brain to make something. Most of the time that interface between hand and brain is lost because all you are doing is clicking. But when I am building something in the computer its very much using the same parts of my brain, I get really close to the screen and I am right there and in there with it.'

Marianne is perhaps slightly different to most practitioners in that she first waited until the material properties were closer to her requirements as a craftsperson before adopting the technology. This means that she is specifically using the material properties of the metal in order to obtain the results she is seeking. However it is clear that Marianne has had to adopt different working practices and develop strategies that take on board the particular material qualities of 3D printed titanium.

Assa Assuach

To create his virtual models for 3D printing Assa Ashuach uses three main software packages. Alias, which is NURBS surface modelling software, primarily aimed at the film and animation industries, then 3D Studio Max (now Autodesk 3ds Max) and SolidWorks for the jobs that require a harder engineering approach, with strict tolerances. He says that over the years, in his furniture for example with its flowing curves, The Alias software, has remained very important to him in order to have the freedom to design fluidly. When he has finalised the designs he will use a bureau such as 3D RPT or Metropolitan works for the printing. Assa uses Studio Max to create designs that

keep geometric tessellation, which for his purposes has to be very organic and natural with no crude intersections, so it all flows together. He uses the analogy of animation in gaming; in particular the way the face and the lifting of the face is programmed to convey emotions. Specifically the modules that re-design the facial expression of the characters, because they have to make sure that when the face expresses, deforms and speaks it needs to happen in a really beautiful and natural way.

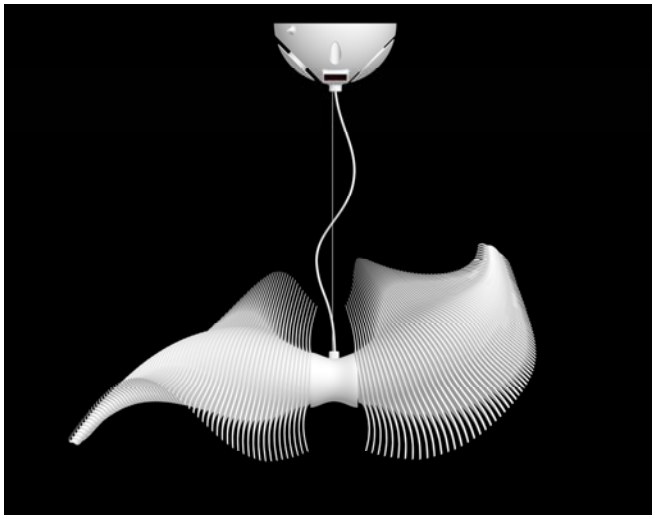

Figure 7 *AI light by Assa Assuach in laser sintered Nylon*

More than 90% of Assa's work is now 3D printed although most of the creative development and product development happens virtually, for the finished designs it is probably more like 100%. He still uses the traditional prototyping process to make conventional prototypes, so he can examine things and check the boundaries of objects. Before sending them through the conventional routes using CNC cutting for milling prototypes. Assa uses a lot of moulding – but all the processes begin with a digital file. At the same time he is mixing plastics and metals and experimenting with 3D printing, with the larger more sculptural pieces he additionally uses fibreglass and carbon fibre. He collaborates with larger companies like Nike, Samsung and Panasonic, in an attempt to understand how we can move into different ways of manufacturing:

'At this moment, this is one of my biggest challenges – is how do we move this technology that I am so familiar with – how do we use it to design better products? And this is not only about crazy lattices and crazy geometries, but it is about offering better products to the user. Assa believes that laser sintered nylon is, at this point in time the best product for mass customisation: 'Nylon is more predictable, more controllable it's robust and easy to finish. If you remove the cost element with Nylon we can already create some good products, especially if you use post processing, like vibro polishing and dye dipping.

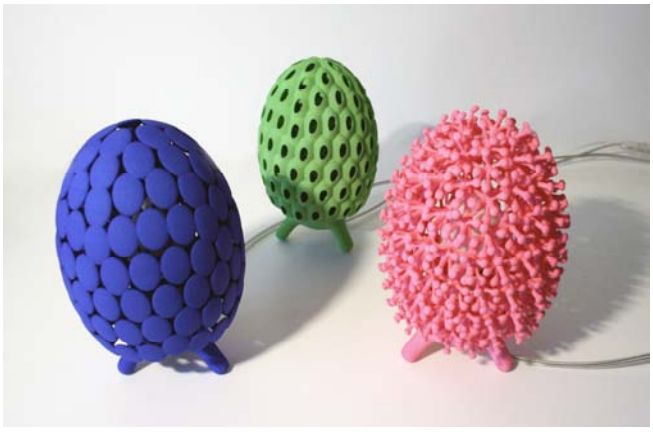

Figure 8 *Bon Bon light by Assa Assuach in dyed laser sintered Nylon*

'I would like to see digital forming as a new design method, because I am designing objects which are in motion, they should be flexible in some way – imagine if you want to bend things – you don't want them to crack and even in the virtual environment when you shape and modify things you really want nice beautiful poly flow and lines of circulations - a bit like making DNA when you want the baby to be healthy in some way. Because we are designing the object – we have to keep in mind that these objects will be modified.'

Figure 9 *Lemon Squeezers by Assa Assuach in dyed laser sintered Nylon*

He believes that the barriers to 3D printing are the material characteristics, or lack thereof: 'Primarily, its all made out of one material – in real terms, its just one solid block of material which has some issues, in one way it's a benefit, there's no assembly.' So he tries to make everything from one material by designing and using the natural flexibility of the nylon. Right now for example, he is designing an foldable chair - all from one printed object - with a gear mechanism inside: 'So imagine you take it out of the machine and in one movement you can open it for the first time and sit on it immediately – so in one way the potential is huge because you don't have people in China (for example) involved in assembly, but this is also where sometimes you say OK but I need another material inside of there too and its oh sorry that's not possible!'

Assa really believes in the concept of time, “if you spend all your time on something and you believe in it and you are passionate about it you’ll gain a very good understanding of that territory, and you’ll become an expert. My belief is that you have to invest so much time in things and you have to learn and educate yourself”. Assa gave the example that given two technicians producing the same design on the same machine, ‘one will talk to the machine in a different way and configure the machine, the speed, the heat and the laser differently, so everything is different – so 3d printing really is not as we believe.’

Conclusion

A new technology has many stages in its adoption process as it progresses from a niche area into a mature universally accepted manufacturing technology. This paper sought to highlight how a practitioners and users perspective can influence that adoption process as it progresses to maturity. In addition it aims to present a different perspective on how a technology may perform a different function to that for which it was designed and offer a note of caution that the end user seldom has a voice into how a technology develops beyond the intention of its original creators. Clearly as a technology matures users will push the boundaries of that technology and creative practitioners in particular will push and adapt those limits due to an inherent understanding of materials, combined with an understanding of the technology itself. I have sought to demonstrate through the case studies that a creative approach other than the direct linear progression, although subjective can enhance the quality of output from a new technology and by following its progress can be seen as an indicator of that technologies maturity.

References

[1] Sennett, Richard. (2008) *The Craftsman*. Allen Lane, London, ISBN 978-0-141-02209-3. pp20

[2] Sturt, George (1923) *The Wheelwrights Shop*. Cambridge University Press. ISBN 0521 06570

[3] Hoskins, Stephen(2013) *3D printing for Artists Designers and Makers*. Bloomsbury, London ISBN 978-1408173794

Author Biography

Stephen Hoskins is Hewlett Packard Chair of Fine Print and Director of the Centre for Fine Print Research at the University of the West of England, Bristol, UK.

Stephen is a Board member of the Association of European Printing Museums, Fellow of the Royal Society of Painter Printmakers and a Member of the Royal West of England Academy. His book ‘3D printing for Artists, Designers and Makers’ is published by Bloomsbury Academic.